Earth resources observation with the Shuttle imaging radar

Charles Elachi
Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California 91109

Abstract

In order to fully understand the radar signature of different surface features and covers, observations must be acquired with a variety of sensor parameters (i.e., frequency, polarization, and incidence angle). This allows the selection of an appropriate set of sensors parameters which will provide the most information about the surface. The Shuttle Imaging Radar (SIR), which is planned by NASA for a series of flights in the 1984-86 time frame, will have the capability to obtain surface images at two frequencies (L-band and C-band), at multiple polarizations, and all incidence angles from near vertical to near grazing. The SIR will operate in the synthetic aperture imaging mode and provide digital images of the surfaces with a resolution of about 20 meters. As part of the SIR flights, a number of planned large-scale experiments will be conducted in the fields of geologic mapping, vegetation classification, land cover mapping, surface moisture measurements, and ocean surface observation.

Introduction

Radar images of the Earth surface acquired with the Seasat spaceborne SAR (synthetic aperture radar) are being used to determine the role of such a sensor in geologic mapping (Elachi, 1980; Ford, 1980; Sabins et al. 1980; Blom, 1981; Dixon, 1981), soil moisture observation, flood monitoring (Mcdonald et al. 1980), ocean waves and surface features monitoring (Gonzalez 1979, Beal 1980) and polar ice motion. The Seasat SAR (Jordan 1980) provided us a look at the Earth surface at a single frequency (1.2Ghz), single polarization (HH) and fixed incidence angle (20° from vertical). Even though this was a step in expanding our capability in spaceborne remote sensing to the active microwave region, the Seasat SAR provided only a single observation point in the multidimensional envelope of capability which can be achieved with radar sensors.

In this paper, I discuss the wave-surface interaction mechanisms which are the basis of the information in the radar images with emphasis on the research activities required to assess and define the type of radar sensor required for specific applications. Then I will discuss the Shuttle Imaging Radar system which is planned by NASA to address these research needs and verify the role of the spaceborne SARs in Earth observation.

Wave-Surface Interactions

The radar image is a two dimensional representation of the backscatter intensity which results from the interaction of the radar wave with the surface being imaged. The backscatter intensity is mainly dependent on: 1) The surface attitude relative to the incident wave; 2) the surface or surface cover roughness relative to the wavelength of the incident wave; and 3) the surface and near surface dielectric properties.

In geologic structural mapping, surface features, patterns and slopes are observed in the radar image mainly because of the backscatter dependence on the surface local attitude. The radar backscatter is very sensitive to surface slope variations (relative to the incidence angle). Figures 1 and 2 illustrate some of the surface structural features which are observed mainly due to variations of the surface attitude in a recognizable fashion. To further the capability of radar sensors in structural mapping there is a need to obtain radar images over a wide range of incidence angles (which could also allow stereo imaging) and illumination direction. The strong effect of the illumination direction is illustrated in figure 3.

In lithologic mapping, soil moisture observation (figure 4), polar ice classification (figure 5) and similar experiments, the image intensity is the main information used. In relatively flat terrain, this intensity is a function of the surface roughness relative to the wavelength and the surface dielectric constant. Observation at multiple frequency, multiple polarization will allow improved identification and classification of surface units. Lithologic units could be differentiated if they weather differently (different surface roughness) or have different dielectric constant (due to moisture, porosity of rock composition).

Soil moisture could be measured from the intensity of the backscattered wave. However in order to separate the effect of the roughness from the effect of the dielectric constant variation (which depends on the moisture content) it might be necessary to use multiple frequency and/or multiple polarization observations.

Another type of radar image information which seems to be very useful is the texture. Ford (1980) and Dixon (1981) used the radar image texture to separate regions of different lithology in the heavy forested regions of the Appalachian and the Caribbean. Fasler (1980) used the image texture in classifying land use in urban areas. However it is not well understood how does the image texture vary with the sensor parameters and if additional information could be extracted with multiparameters observations.

Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx

Characteristics of the Shuttle Imaging Radar

To be able to conduct the research needed to address the above and similar investigations, a Shuttle Imaging Radar (SIR) system is planned by NASA for launches in the 1984-1986 time frame. The SIR will be a multiparameter flexible system, with a wide envelope of capabilities, which can be reconfigured during flight to conduct a variety of experiments. The characteristics of the SIR are summarized in Table I and an example of some of the experiments which could be conducted with it are illustrated in figure 6. The large flexibility of this system require the use of the Shuttle as a platform, otherwise the sensor cost will be prohibitive if it is configured for a free flying platform.

Conclusion

The SIR is planned as the key research sensor to develop the capability (application, techniques and technology) for future spaceborne SAR systems. It will be used to conduct a large number of the research investigations required to achieve this capability. However, because of the limited orbital time capability of the Shuttle some research investigations will still require the use of a free flying SAR system with fixed configuration. Specifically these are the investigations which require long term monitoring of dynamic phenomena or global mapping. Therefore, the flexible SIR will be one of the two key elements (the second being the fixed flying sensor) in an experimental program to achieve an operational spaceborne radar capability in the early 90's.

References

Beal R., 1980 "Spaceborne Imaging Radar - Monitoring of Ocean Waves" Science, 208, pp 1373-1375

Blom R., M. Abrams and C. Conrad, 1981, "Rock Type Discrimination Techniques Using Landsat and Seasat Image Data". International Geoscience and Remote Sensing Symposium, June 8, Washington, D. C.

Dixon T., 1981, "Analysis of Jamaican Lineaments Visible in Seasat SAR Imagery", International Geoscience and Remote Sensing Symposium, June 8, Washington, D. C.

Elachi, C., 1980 "Spaceborne Imaging Radar: Geologic and Oceanographic Applications", Science, 209, pp 1073-1082.

Ford, J., 1980 "Seasat Orbital Radar Imagery for Geologic Mapping: Tennessee-Kentucky-Virginia" AAPG Bulletin 64, pp 2064-2094.

Gonzales F. I., et al., 1979, "Seasat Synthetic Aperture Radar Ocean Waves Detection Capabilities", Science, 204 pp 1418-1421.

Jordan, R., 1980, "The Seasat-A Synthetic Aperture Radar System", IEEE J. of Oceanic Engineering, OE-5, pp 154-163

Sabins F., R. Blom and C. Elachi, 1980, "Seasat Radar Image of San Andreas Fault, California", A.A.P.G. Bulletin 64, pp 619-628.

Acknowledgments

This paper represents the results of one phase of research carried out at the Jet Propulsion Laboratory, California Institute of Technology under Contract No. NAS 7-100, sponsored by the National Aeronautics and Space Administration.

Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx

Table 1

SIR Characteristics

Operating Frequency	L-band and C-band
Look Angle	Variable from 15° to 75°
Polarization	HH on L-band HH, VV, HV and VH on C-band
Resolution	10m in high resolution mode 30m in low resolution mode
Swath Width	Variable between 35Km and 125Km
Antenna Length	12 meters
Antenna Width	2.16m for L-band antenna 0.5m for each one of the C-band antennas
Data Hanlding	Real-time transmission to ground via TDRSS in digital form. Also optical recording on board
Data Processing	Digital and Optical

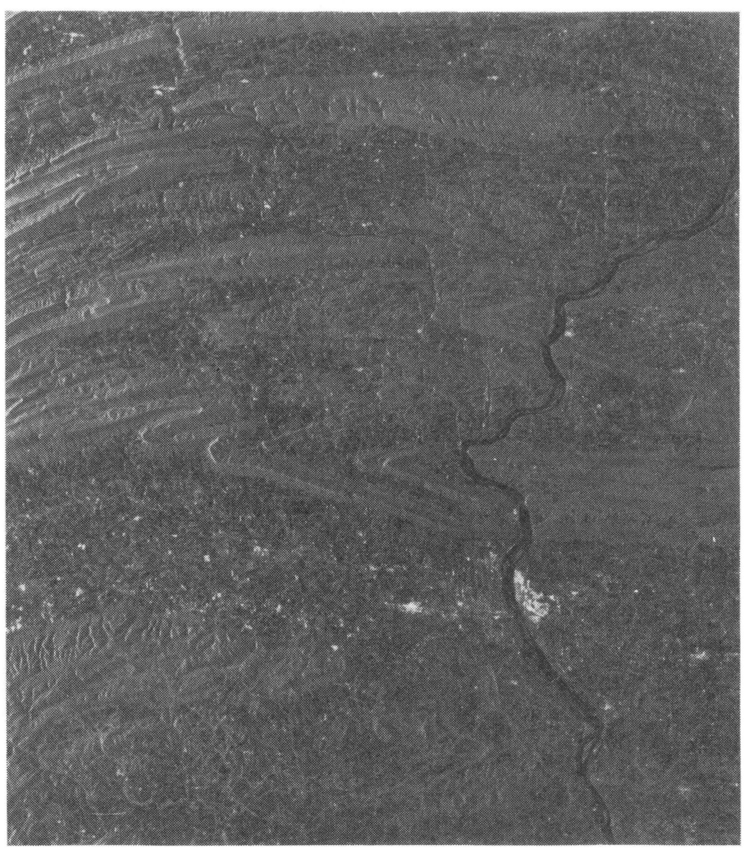


Figure 1

Folded terrain in the Harrisburg region of Pennsylvania as imaged by the Seasat SAR. The series of anticlinal and synclinal features are visible mainly due to their topographic expressions. The illumination in this image is from the left. Image size is 90 x 90 km.

Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx

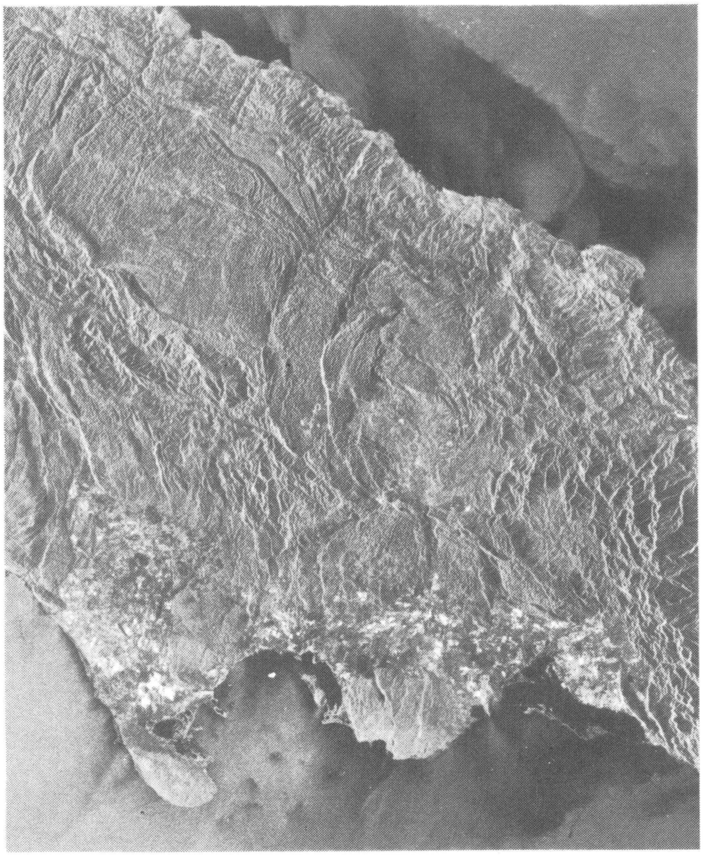


Figure 2: Seasat SAR image of Karst terrain in central Jamaica. The Karst region and numerous lineaments, some of which correspond to known faults, are visible due to their characteristic topographic expressions. The illumination is from the left. Image size is 90 x 100 km.

(a)

(b)

Figure 3: Two Seasat SAR images of the region near Knoxville, Tennessee in the Appalachian. The two images were acquired with two illumination direction, one from the southwest (figure a) and one from the southeast (figure b). Observe in particular the major syncline (Clinch Mt. Syncline) at the right side of the images.

Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx

(a)

(b)

Figure 4: Two Seasat SAR images of the region near Evanston, Wyoming. Figure (b) was acquired on September 18, 1978. Figure (a) was acquired on August 1, 1978 immediately after a rainstorm. The bright regions most likely correspond to the areas of high soil wetness.

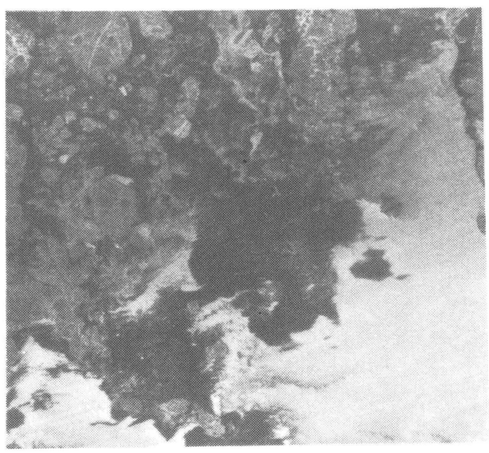
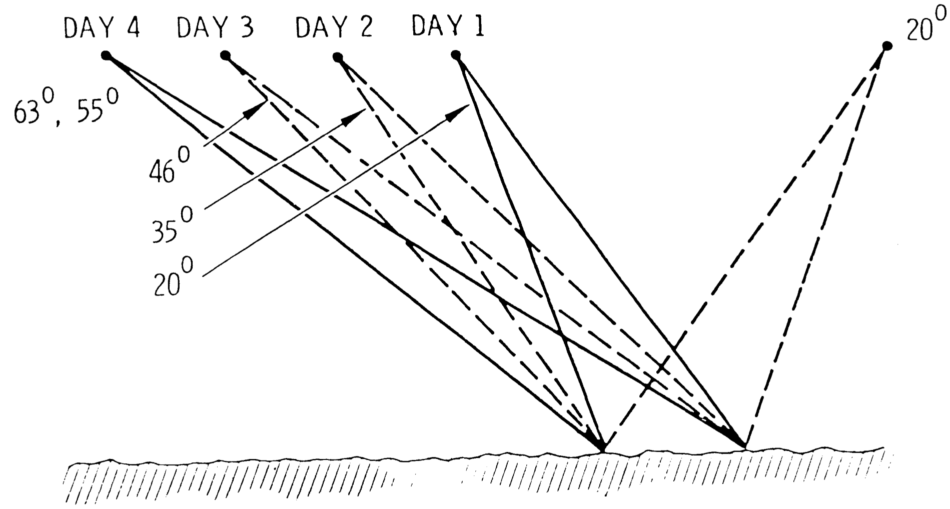
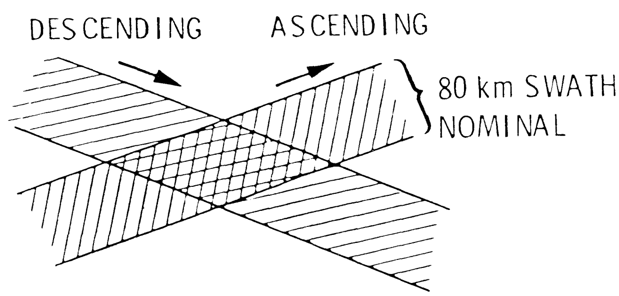


Figure 5: Seasat images of polar ice west of Banks Island. The ice flows can be recognized due to their shapes. Ice motion was measured by using images acquired successively every three days. Image size is 90 x 90 km.

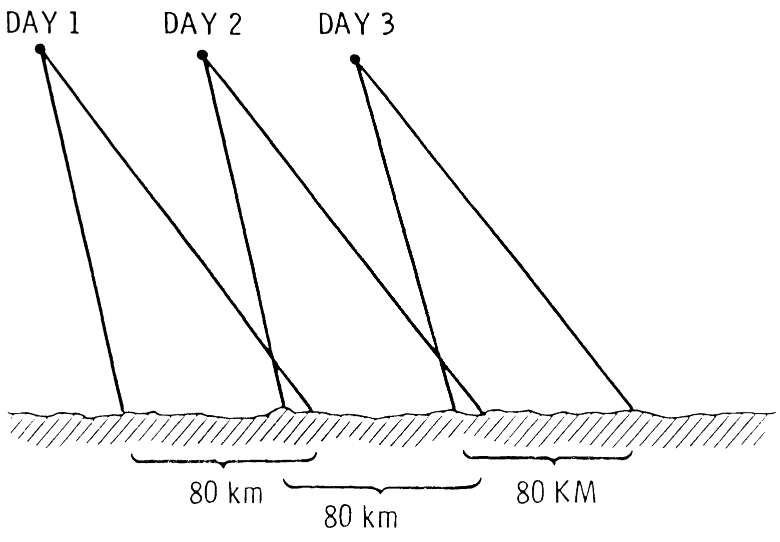
Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx



(a)



(b)



(c)

Figure 6: Some of the kind of experiments which could be conducted with SIR: a) Multiple incidence angle observation, b) multiple look direction observation, c) large areal coverage.

Downloaded From: http://proceedings.spiedigitallibrary.org/ on 10/28/2015 Terms of Use: http://spiedigitallibrary.org/ss/TermsOfUse.aspx